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**FULL CONTENT FILM SCANNING ON A FILM TO DATA TRANSFER
DEVICE**

EASTMAN KODAK COMPANY
RESTRICTED INFORMATION

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CROSS-REFERENCE TO RELATED APPLICATION(S)

5 Reference is made to commonly assigned copending application
Serial No. [our Docket No. 83295], entitled "Calibration of a Telecine Transfer
Device for a Best Light Video Setup" and filed on even date herewith in the
names of R. J. Cirulli, K. J. Alvut and M. M. Mendel.

FIELD OF THE INVENTION

10 The invention relates generally to improvements in the field of film
scanning, and in particular to improvements in the transfer of motion picture film
to a digital signal that is especially adapted for film recording.

BACKGROUND OF THE INVENTION

15 As generally shown in Figure 1, in the motion picture industry an
original motion picture negative film is exposed during a camera exposure
operation 10, developed into a processed camera negative 12 and subsequently
processed in one of several ways. In the motion picture industry, there are two
20 common subsequent processes: an optical printing process 18 and a film scanning
process 20. It is well known that the optical printing process may be practiced in
several ways in order to optically transfer the image data to a print material. In a
single stage optical process, the optical transfer is direct; that is, the color negative
film 12 is optically printed onto another photosensitive material, e.g., a release
25 print material 22 such as Eastman Color Print Film 5386™, to produce a color
positive image suitable for projection. To avoid harming the original negative in
the subsequent processes, the camera negative 12 may be converted into an
interpositive 14, which is a positive image optically produced on a negative
copying material with the same contrast and the same extended range of the scene
30 as the camera negative. (Either element 12 or 14 then constitutes the photographic
film element 16 identified in Figure 1, which is subsequently processed.) In such
a multi-stage process, the optical transfer of the original image data to a print

material is indirect; that is, the interpositive 14 is used to optically produce numerous duplicate negatives 24, which are then optically printed (process 26) onto release prints 28, which may also be Eastman Color Print Film 5386™.

In the other subsequent process in the motion picture industry, the color negative film information (camera negative 12) or the color print film information (interpositive 14) is transferred into a video signal using a telecine transfer device in the telecine scanning process 20. (As with the optical scanning process, the interpositive is a negative copying material that is used to produce a positive with the same contrast as the original negative and the same extended range of the scene; this element is then used in the trade as the element to scan on the telecine device without risking harm to the original negative.) Various types of telecine transfer devices are described in *Engineering Handbook*, E.O. Fritts, Ed., 8th edition, National Association of Broadcasters, 1992, Chapter 5.8, pp. 933-946, the disclosure of which is incorporated by reference. The most popular of such devices generally employ either a flying spot scanner using photomultiplier tube detectors, or arrays of charged-coupled devices, also called CCD sensors. CCD sensors include either an area array scanner (captures the full frame at once) or a linear line scanner (the film is transported across a line array of sensors and the total image is then a reconstruction of all the lines to give an area image). Telecine devices scan each negative or positive film frame transforming the transmittance at each pixel of an image into a voltage. The signal processing then inverts the electrical signal in the case of a transfer made from a negative film in order to render a positive image. The signal is carefully amplified and modulated, and fed into a cathode ray tube monitor 30 to display the image, and/or recorded onto magnetic tape for storage in a recording stage 32. The output of the telecine scanning process 20 may be applied to a film recording stage 34, which produces a negative film 36 that can be optically printed out as a release print.

The monitor 30 is typically a high definition (HD) monitor with the data provided from the telecine scanning process 20 incorporating the characteristics of the monitor such that the video image is pleasing to the operator. In this use of the telecine transfer device, only a restricted range of the total image on the film element 16 is used (i.e., compressed into the tonal range of the

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monitor). If a video tape is desired from the video recording process 32, the data associated with the image displayed on the monitor is written to digital (or analog) tape. If digital data is required for the subsequent film writing process 34, the telecine device has an output data pathway which includes one dimensional look up tables (1D LUTs) 38 that transform a video tone scale to a more film like tone scale such that the resulting negative 36 produced will print onto a photographic print element 28 and look at least somewhat like a film system image. The video monitor image, however, usually will not match the final print image in tone scale and color reproduction.

10 In the previous examples from the prior art, the digital data acquired in the telecine scanning process 20 only has the restricted range of the initial video range capture. If the client desires changes to the final look, the operator can only modify the data obtained. If there was information on the photographic film element 16 outside of the range initially captured, then it is not
15 represented in the data and cannot be used. An example of this could be an interior scene with a person sitting at a desk with an outside window in the background. In a normal telecine transfer, the very high exposure of the outside window relative to the proper lightness of the interior foreground will show up as a very light area without much detail. However, the film element has considerable
20 detail in this area but without advanced technical techniques it cannot be displayed on the HD monitor. The extended range can be captured in a second scan through the telecine scanning process 20 with a different setup that maximizes the high exposure area. The two scans can then be merged with advanced digital techniques. One drawback of this technique is that the extended range that needs
25 to be captured must be known at the time of the original scan, otherwise a future new scan is required with added cost. Moreover, while the desired transfer would capture the entire extended range of the negative, in the current system the HD monitor would be unable to effect correct tone scale and color reproduction and thus would be useless as a creative display device.

30 In the motion picture trade, some postproduction facilities use a technique that tries to capture the complete negative range. In this technique, the highest density on the negative is assigned to the highest video level and the

lowest density on the negative is assigned to a low video level (usually not the full low to high range available in the bit depth of the transfer). This data can then be color corrected on another device, which inputs data and allows digital manipulation to give an image on a monitor that is pleasing to the client. In either case another device, usually another computer system, is employed in an attempt to show a film look from the data to validate the image content before committing to film recording.

In current telecine transfer practice, there is no assurance that the data will render on film (by means of a film recorder) as intended. The dynamic range on the negative is not preserved in a consistent manner. Moreover, the current telecine transfer practice of viewing the scanned video data on a HD monitor and then writing to data (and film) through a 1D LUT can produce changes in the very low tones (blacks and very dark colors) in the data that are not able to be displayed on the monitor.

For a effective film recording process, what is ultimately needed is a telecine transfer process that produces data that can be used, without operator intervention, as input to a film-recording device to produce a negative, which will result in a print that matches a print optically produced from the original negative.

SUMMARY OF THE INVENTION

The present invention is directed to overcoming one or more of the problems set forth above. Briefly summarized, according to one aspect of the present invention, a method of transferring an image recorded on a photographic film to a digital signal, using a film scanning device that generates scan data representative of the digital signal, comprises the steps of calibrating the film scanning device in relation to printing densities and scanning the photographic film with the film scanning device to produce scan data that represents printing densities. Inasmuch as the digital signal is used to drive a film recorder that exposes an output film that is subsequently printed onto a target print material, the scan data represents printing densities which when written out to the film recorder will produce printing densities of the output film onto the target print material that

are identical to the printing densities of the same photographic film optically transferred onto the target print material.

The present invention thus refers to a method of capturing the full content of a photographic element on a telecine scanning device. By capturing the full content of a photographic element, the advantage is that the resulting data can be used as input to a film-recording device without operator intervention to produce a negative, which will result in a print that matches a print from the original negative. In this way, the need for color grading on a scene-to-scene basis during the film scanning process is avoided. Thus, the time involved in the initial scan is significantly reduced and the complete representation of the scene is available for postproduction data-to-data manipulation. The postproduction data-to-data manipulation is usually a computer disk-to-disk operation, and in this case the full range of the scanned film element is available in one scan to achieve the desired look of the creative person directing the color transformation.

These and other aspects, objects, features and advantages of the present invention will be more clearly understood and appreciated from a review of the following detailed description of the preferred embodiments and appended claims, and by reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of the motion picture postproduction process, as known in the prior art, which is useful in forming an understanding of the invention.

FIG. 2 is a block diagram of a telecine transfer device that may be calibrated in accordance with the invention to provide calibrated code values for a film writing process.

FIG. 3 is a flow chart showing the calculation of digital code value aims.

FIG. 4 is a flow chart of the calibration process according to the invention, which uses the digital code value aims calculated in Figure 3 to calibrate the telecine shown in Figure 2.

FIG. 5 is a diagram of a calibration element useful in the calculations and calibration processes shown in Figures 3 and 4.

DETAILED DESCRIPTION OF THE INVENTION

5 Because telecine and other film scanning devices employing cathode ray tubes (CRTs) or electronic sensors are well known, the present description will be directed in particular to elements forming part of, or cooperating more directly with, the calibration technique in accordance with the present invention. Elements not specifically shown or described herein may be
10 selected from those known in the art.

The data generally used in the trade for film recording is a 10-bit log format. This is not just a mathematical logarithm but also a precise 10-bit digital representation of the negative's printing density. The term "printing
15 density" is a reference to a density metric similar to the industry standard Status-M density. In this discussion both Status-M and printing density will refer to three integral red, green and blue channels. In a density metric there is a conversion of linear transmittance to log (density) by the equation:

$$\text{Integral Density} = -\text{Log (Integral Transmittance)}.$$

20 The Integral Transmittance metric is a measure of the degree that an element alters the effective intensity of a light source. The mathematical computation of the integral transmittance of a photographic element such as a color negative is dependant on the spectral transmittance curve (transmittance at predefined
25 wavelength increments, i.e., 10nm) of the element to be measured as well as the spectral power distribution of the light source and the spectral sensitivity of the detecting device. For example, the red integral Status-M transmittance is the sum of the wavelength-by-wavelength products of the spectral transmittance of the film element and the normalized spectral power distribution of the light source
30 and the normalized red spectral sensitivity of the Status-M detecting device. Similarly, the red integral printing density transmittance is the sum of the wavelength-by-wavelength products of the spectral transmittance of the film

element and the normalized spectral power distribution of the printing light source (motion picture film printer light source spectral distribution) and the normalized red spectral sensitivity of the print film spectral sensitivity. The green and blue channels are calculated in similar fashion. Thus, a Status-M density is a standard
5 traceable to a standards reference document. However, a printing density is really a density representation as to how the photographic print element "sees" the dyes of the film element and predicts the independent red, green and blue channel attenuation in the printing process. It is clear that for any specific Status-M density of a particular film element there is an infinite number of sets of printing
10 densities that depend on the printer lamp house and the characteristics of the print material.

The 10-bit log format also provides for a scaling. A code value (CV), from a range of 0 to 1023 (10 bit = 1024 states), represents 0.002 in printing density. Therefore, the complete 10-bit range of code values represents 2.046 in
15 printing density. This 2.046 printing density range corresponds to a scene exposure range of approximately 3.72 log exposure (approx. 12.4 stops) for a film with a gamma of 0.55. A hypothetical film with a gamma of 0.5115 with a log exposure range of 4.0 (approx. 13.33 stops) could also be expressed in the complete code value range.

This invention centers about the idea, in terms of Figure 1, that
20 with a specific calibration to printing density, the telecine device can accurately capture the information on the film element 16 in such a way that the resulting code values represent true printing densities which when written out to a properly calibrated film recorder 34 will produce printing densities of the output film 36
25 onto the target print material 28 that are identical to the printing densities of the same film element 16 optically printed onto the target print material 22 (or 28). Thus, in the end, a print 28 optically produced from the recorder-generated negative 36 via the telecine scanning process 20 will match, in tone scale and color reproduction, the print 22 (and 28) optically produced from the original film
30 element 16 via the optical printing process 18 (and 26).

Referring to Figure 2, which shows a telecine transfer device in more detail, a film transport 40 advances a motion picture film 41 at a

substantially uniform speed through a film gate 42 from a supply reel 43 to a take up reel 44. A light source 45 generates a light beam that is directed through a circle to line converter 46 and focused upon a linear section of the film 41 in the film gate 42. The light is modulated by the image in the film 41 and transmitted
5 through an objective lens 47 to a beam splitter 48, which transmits one portion of the light to an unsharp color sensor 49 and reflects the other portion to a high resolution luminance sensor 50. The color sensor 49 comprises three linear color arrays respectively sensitive to red, green and blue light. The luminance sensor 50 includes a linear array sensitized to light having a spectral composition
10 approximating a luminance function. A sensor clock generator 51 provides a clock signal of appropriate frequency(s) for shifting the respective image signals from the output registers of the color sensor 49 and the luminance sensor 50.

The luminance sensor 50 produces a full resolution signal according to the requirements of the high definition standard, or the film scanning
15 standard, in use. Low resolution, or unsharp, color is provided from the color arrays comprising the color sensor 49, allowing the color photosites to be accordingly larger, which has the advantageous effect of increasing the signal-to-noise performance. The unsharp color sensor 49 provides three channels of color data to an analog-to-digital converter 52 and the luminance sensor 50 provides a
20 high resolution data stream to another analog-to-digital converter 53. Because the three color arrays comprising the color sensor 49 are spaced in the direction of film motion, the fixed mis-registration of their output signals is corrected in color registration circuit 54. Since the digital color values represent lower resolution data than the digital luminance values, additional color values are generated in a
25 color interpolation circuit 56 in both the horizontal and vertical directions. Meanwhile, high frequency detail is extracted from the luminance data by a detail extraction circuit 58 and added to each channel of color in an addition circuit 60, forming thereafter a full resolution, three channel, high definition color output signal. This high definition signal is applied to a digital processor 61, which can
30 apply adjustments to the high resolution signal as determined from a telecine control section 62. A colorist would operate the telecine controls 62 to adjust the lift (dark areas), gain (highlights) and gamma (mid-tone) of the images produced

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by the high resolution signal. The control section 62 also includes an adjustment for the light level of the light source, which is communicated to a light source controller 63.

5 The full resolution, three channel, high definition color output signal from the digital processor 61 is further processed either as a video output through an image store 64 or as a data output through a data interface 66. The image store 64 includes a first framestore 64a, a second framestore 64b and an interlace controller 64c for loading the high resolution data into one framestore while extracting high resolution video fields in interlace format from the other
10 framestore. The output of the image store 64 can be applied, referring to Figure 1, to the monitor 30, after suitable adjustments for transfer characteristics by means of look-up tables (LUTs), or to a digital (or analog) video recording stage 32. The full content film scan data output from the data interface 66 may go to DVD, CD, VHS, an HD master, film output, and the like. For instance, as shown without
15 limitation in the preferred embodiment, the data output from the data interface 66 is applied to the film recording stage 34. (In this case, the 1D LUTs 38 would not be used.) Further details of the telecine and its operation can be found in commonly-assigned U.S. Patent No. 5,045,932, "Method and Apparatus for Generating a High Definition Electronic Signal from a Line Scan of a Color
20 Signal", which is incorporated herein by reference.

During calibration of the telecine, a calibration film element 80 (as shown in Figure 5) is manually run through the film gate and scanned. In practice, the actual, specific calibration of the telecine for a variety of filmstocks would use a plurality of calibration film elements, wherein each film element is
25 used to calibrate the system for an accurate extended range printing density scan of a given film having given density-log exposure characteristics (one film element can be used for each set of films with similar characteristic curves). The specific characteristic of the calibration film element 80 is a neutral exposure onto the film element with the light balanced for the color temperature of the design
30 criterion, e.g., whether designed for daylight vs. tungsten, of the film element. This is ordinarily done by a series of exposures on a sensitometer, although a camera could be used to obtain the patches by a series of uniform exposures in

which the aperture and shutter speed are varied in an ordered manner. In the preferred embodiment, the exposure range is chosen from a standard set, in this case a 0 – 4.0 Log Exposure range (approx. 13.33 Stops) which on a film with a gamma of 0.55 reflects a printing density range of 2.20 which is slightly outside of the 2.046 printing density range of the 10-bit log format. As shown in Figure 5, the calibration film element 80 ordinarily includes a plurality of neutral patches ordered into a set, e.g., from light to dark; for instance, as specifically shown in Figure 5, the calibration film element 80 includes twenty-one patches 82 ordered at 0.2 log exposure increments for the 0 – 0.4 log exposure range. (The arrangement in Figure 5 is shown without limitation, i.e., a greater or fewer number of patches may be used, their sizes and separation may vary, and they need not be in ascending (or descending) order of density. Moreover, the movement of the calibration element through the telecine film gate could be automatic, rather than manual.)

In an alternative to the preferred embodiment, the exposure range may be encoded in a greater bit depth; for example, if a 12-bit log format were adopted (0 – 4095 CV) and the current 0.002 printing density to CV scaling applied, then a printing density range of 8.19 could be accommodated. If, instead, the printing density to CV scaling was 0.001, then a printing density range of 4.095 could be accommodated. This would capture a 7.45 log exposure range on a gamma 0.55 film (24.8 Stops), far greater than is required for even advanced imaging. However, the current limitation of available technology is the linear bit depth of capture, which is 12-bits and which correlates well with the 10-bit Log format. When a greater linear bit depth of capture is available, at least 14-bits linear and preferably 16-bits linear would fit well with the 12-bit log format.

Figure 3 shows the steps involved in generating the digital code value aims that are used in the calibration process. Initially, in a measurement step 90, the calibration film element 80 described above is measured on a spectral instrument to determine the spectral transmittance curves for each of the patches of the calibration element (e.g., for the 0 – 4.0 Log Exposure calibration film element 80 shown in Figure 5 the usual exposure increment is 0.20 Log Exposure for a total of 21 patches). The obtained measurements are applied to a printing

density aim calculation step 92 where the data is used as described above to calculate the printing density aims for the calibration, basically by summing, for each color, the wavelength-by-wavelength products of the spectral transmittance of the film element, the normalized spectral power distribution of the printing
5 light source and the normalized spectral sensitivity of the print film spectral sensitivity. Then, in a conversion step 94, the printing density aims are converted to digital code value aims by, e.g., dividing through by 0.02 to obtain code values. In a storage step 96, the digital code value aims are stored in a storage associated with the digital processor 61 (Figure 2).

10 Figure 4 shows the steps involved in calibrating the telecine to the digital code value aims that were generated in the preliminary steps shown in Figure 3. Before beginning the calibration process as shown in Figure 4, the telecine device is first set into its center TAF (from Eastman Kodak Company's Telecine Analysis Film) setup mode. The TAF setting is a well-understood
15 industry standard that is used to center the controls of a telecine device, and it sets the starting tone scale and color position to the TAF reference chart. Then, the calibration film element 80 is loaded onto the telecine device in a loading step 100. In a scanning step 102, the calibration film element 80 is scanned on the telecine and the scan data is saved. This scan data is then transferred into digital
20 code values in a transfer step 104. In a comparison step 106, the digital code values are compared to the digital aim code values, which have been calculated in the process shown in Figure 3 and stored. If the values are unequal (decision step 108), the calibration process initiates an adjustment 110 of the digital telecine controls 62 (Figure 2).

25 To perform the calibration, an experienced colorist (telecine operator) manipulates the telecine primary controls 62. The goal is to adjust the telecine data signal so as to achieve the aim output code values of each patch of the calibration film element 80. There are a number of parameters to change on the telecine device to achieve this goal, including one or more of the following
30 adjustments:

a. Light level of the light source 45 may be adjusted to accommodate the D-min and the D-max of the calibration film element 80.

b. The 3x3 Masking matrix for the film type. This is the matrix in the telecine hardware that corrects for crosstalk in order to obtain a channel independent representation of the color dyes in the film element.

5 c. Matching blacks, i.e., setting RGB levels to obtain a desired black.

d. Matching whites, i.e., setting RGB levels to obtain a desired white.

e. CRT gamma off/on.

f. Lift, i.e., adjusting detail in the black areas.

10 g. Gamma, i.e., adjusting contrast in the mid-tone areas.

h. Gain, i.e., adjusting brightness in the highlight areas.

i. Data output lookup table in the Telecine, i.e., adjusting a LUT in the output data stream that can modify the output signal (could be a unity matrix).

15 j. Offsets in the RGB output.

Each of these adjustments are conventional adjustments available on a telecine or a data telecine, such as the Spirit DataCine™ available from Thomson, and would be familiar to a colorist of ordinary skill in the art.

20 After the telecine control adjustments are made, the scan of the calibration film element 80 is repeated in the scanning step 102 and the subsequent process is repeated until the obtained code values (from the scan) are found to be equal (step 108) to the aim code values. Then the telecine control setups are saved in the storage step 112 and telecine transfer of a filmstock may commence. Each film type potentially requires a different calibration setup
25 (assuming each film type has different film characteristics) that is stored and retrieved when that film type is being run on the telecine. In practice, the resulting plurality of calibration setups (at least one for every film type) can easily be managed by using metadata in the form of KeyCode (which are computer readable markings provided on the film that specifies the film type) to select the
30 proper setup.

The principal reason for this type of calibration is that film scenes that are subsequently scanned with the telecine set up in this manner may be

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directly written to film to produce a match to the original film element, and in particular without any other postproduction processing required in order to obtain such a match. Moreover, the scanning may be accomplished without requiring the colorist to constantly be making color grading decisions. The scanned data,
5 however, would not be suitable for direct viewing on the monitor 30 (Figure 1) as in the normal video mode. It has been found that a reasonable representation can be viewed on a system, such as the Cineon™ system offered by Eastman Kodak Company, with a film-calibrated monitor.

The benefit of this invention is that a postproduction facility could
10 have a single (or few) telecine devices which could scan very fast, without making color grading decisions, and the resulting data could go a disk-to-disk final color grading at a later time, and even at alternative sites. This procedure also lowers the effective transfer time, which minimizes the potential problem of dirt collection during transfer. Dirt removal from digital data elements is costly in time and
15 money. The saving of time, money, flexibility and accuracy to film is unprecedented in motion picture postproduction.

The invention has been described with reference to a preferred embodiment. However, it will be appreciated that variations and modifications can be effected by a person of ordinary skill in the art without departing from the
20 scope of the invention.

PARTS LIST

- 10 camera exposure operation
- 12 camera negative
- 14 interpositive
- 16 photographic film element
- 18 optical printing process
- 20 telecine scanning process
- 22 release print
- 24 duplicate negative
- 26 optical printing process
- 28 release print
- 30 monitor
- 32 video recording stage
- 34 film recording stage
- 36 negative
- 38 1D LUTs
- 40 film transport
- 41 motion picture film
- 42 film gate
- 43 supply reel
- 44 take up reel
- 45 light source
- 46 circle to line converter
- 47 objective lens
- 48 beam splitter
- 49 unsharp color sensor
- 50 high resolution luminance sensor
- 51 sensor clock generator
- 52 A/D converter
- 53 A/D converter
- 54 color registration circuit
- 56 color interpolation circuit

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58	detail extraction circuit
60	detail addition circuit
61	digital processor
62	telecine controls
63	light source controller
64	image store
64a	first framestore
64b	second framestore
64c	interlace controller
66	data interface
80	calibration film element
82	patches
90	measurement step
92	printing density aim calculation step
94	conversion step
96	storage step
100	loading step
102	scanning step
104	transfer step
106	comparison step
108	decision step
110	telecine controls adjustment step
112	storage step